6-1-1971

Computer Application of Historical Data

Raymond Wright

COMPUTER APPLICATION OF HISTORICAL DATA

A Study Report
Presented to
the Faculty of the Graduate School
Rochester Institute of Technology

In Partial Fulfillment
of the Requirements for the Degree
Master of Business Administration

by
Raymond J. Wright

June 1971

COMPUTER APPLICATION OF HISTORICAL DATA

by

RAYMOND J, WRIGHT

Submitted

OCTOBER 1970

Approved ________________________, Advisor

HOLLISTER SPENCER
ASSOCIATE PROFESSOR

Approved ________________________, Dean

JERRY YOUNG
COLLEGE OF BUSINESS

PREFACE

THIS RESEARCH EFFORT AND THE RESULTANT COMPUTER PROGRAM REQUIRED ACCESS TO DATA AND FACILITIES NOT AVAILABLE TO ALL COMPANY EMPLOYEES. I WOULD LIKE TO EXPRESS MY APPRECIATION TO MY IMMEDIATE SUPERVISOR, MR. E. EDWARD LOWERY, WHO ACTED ON MY BEHALF TO MAKE THIS RESEARCH A REALITY. I ALSO EXPRESS MY APPRECIATION TO DR. HOLLISTER SPENCER WHO PROVIDED THE NECESSARY GUIDANCE DURING THE WRITING OF THE FINAL RESEARCH REPORT.

CONTENTS

		Page
LIST OF TABLES		vii
LIST OF FIGURES		viii
Chapter		
I	INTRODUCTION	1
	USE OF ANALYSIS DATA	2
	RESEARCH PROPOSITION	4
	PRESENT ANALYSIS	4
	CRITERIA	6
II	METHODOLOGY OF DATA COLLECTION AND ANALYSIS	7
	DATA COLLECTION	7
	DATA FLOW	8
	METHOD OF ANALYSIS	12
	DATA RETRIEVAL REQUIREMENTS	15
	INPUT/OUTPUT DATA FORMAT	19
	DATA RETRIEVAL EQUIPMENT IDENTIFICATION	22
III	ANALYSIS OF RESEARCH	25
	DISCUSSION OF DATA ITEMS	25
	SPECIFIC MODEL APPLICATION	29
	APPLICATION OF MEASUREMENT CRITERIA	31
IV	LIMITATIONS	35

CONTENTS (Continued)

		Page
V	APPRAISAL OF RESEARCH STUDY	38
	AREAS FOR EXPANSION	38
	COMPARATIVE LITERATURE FINDINGS	39
	MANAGEMENT USE	46
SELECTED BIBLIOGRAPHY		49
APPENDIXES		51
A.	SAMPLE FORMS OF HISTORICAL DATA	52
B.	COMPUTER PRINTOUT NEWSYSTEM SIMULATION	59

LIST OF TABLES

Table		Page
II-1	EQUIPMENT CLASSIFICATION LIST	24
V-1	SYSTEM AVAILABILITIES	43

LIST OF FIGURES

Figure		Page
II-1	DATA FLOW	9
II-2	MAINTAINABILITY PREDICTION WORKSHEET	16
II-3	INPUT DATA FORMAT	21
V-I	EQUIPMENT AVAILABILITY	45

Chapter I

INTRODUCTION

There always exists the need, somewhere, and by someone, to have more information for analysis, and to have this at an earlier point in time. What may be supplied in sufficient detail and within a reasonable time period for one use may be partially or totally inadequate for meeting the requirements of another use.

This research was not undertaken to attempt to find a remedy for everyone's time and data problems, but rather to satisfy a present and often repeated need which is important within the researcher's department, specifically the Product Assurance department, and within the company, General Dynamics, in general. This response to an immediate need will highlight some useful applications to similar business requirements. This research is conducted within an electronics industry and is primarily oriented toward military communications systems rather than commercial radio, TV, etc.

Analysis data is particularly important for use in proposal and special studies efforts. Proposal and special studies requirements, in general, require a written description of the work to be done by the one responding to the the proposal or study within each department, and the method of accomplishing the proposed tasks once the formal approval has been granted. These, in turn, are based upon the particular proposal or study item under consideration and its overall complexity and magnitude of functional operation. The item is described physically and functionally as best as possible, because normally it exists only in the conceptual or proposal phase. The item is also described quantitatively as to the desired and/or expected performance measurement which it is to meet. Even though the item is only proposed, and not yet existent, the more definitive each description, the more relevant the associated data.

Industry in general, and specifically those involved with government space and defense contracts find it an invaluable, if not demanding, requirement to perform such an analysis study. Military contracts are now, more so than a few years ago, requiring that an evaluation and analysis be made in advance of contract placement. This evaluation and analysis must be for all systems, subsystems, and equipment items as specified by their proposal efforts, special studies, logistics apportionment, and economic trade-off studies. Considering that most of this effort is related to items only in the conceptual or proposal phase, one can realize the amount of effort involved.

USE OF ANALYSIS DATA

The analysis data for proposals and special studies required the prediction of such factors as maintenance task times, frequency of occurrence, personnel requirements and obtaining an overall system quantitative analysis in an effort to effect better bids to proposals and better data for studies. The analysis data then assists in providing the following:

a. Provide a basis for allocating or apportioning quantitative requirements (prior to actual design) given an overall end item constraint (e.g., availability, mean-time-to-repair, etc.). End item is the term used to denote the final resultant item whether it be a single piece of equipment or a console consisting of several items all functionally operating as one unit.

b. Serve as a basis for measuring system/equipment design. Measurement is accomplished through a quantitative prediction of: MTTR (mean-time-to-repair), MMM/OH (maintenance time per operating hour), MTBM (mean-time-between-maintenance which includes scheduled and unscheduled events), and MTBMA (mean-time-between-maintenance-action).

c. Provide a data base from which all support requirements (e.g., tools, test equipment, spare/repair parts, maintenance tasks, and personnel) are derived.

An overall analysis requires many inputs and considerable time. The limitation of time and opportunity for coordinating these inputs is often such that the desired analysis response is untimely. It is untimely in that the overall response, by the company, has to be completed within a specific time. Each response has a different time requirement. An average of fifteen days in which to respond is not uncommon. Thus the limitations often prevent a complete closed loop system analysis approach. In many cases some data must be either prohibitive due to these restraints, and use of an alternative set of data is rarely possible though often desired. The analysis is applicable to all phases of the program. Specific aspects of the analysis are applicable to the initial maintenance allocation as well as application to trade-off studies. This analysis in turn serves as a design measurement device. With the present need and the anticipated future demand for meeting competition, industry must be able to respond both quickly and accurately to these data needs.

RESEARCH PROPOSITION

In an effort to improve the method of supplying analysis data for responding to proposals and special studies, the following proposition is stated:

> The application of historical maintenance analysis data, when subjectively applied to a proposed system data model, will provide analysis data capable of meeting proposal and special studies requirements.

PRESENT ANALYSIS

Historical maintenance analysis data is a product of both quantitative and qualitative data inputs from various organizational groups. These groups represent, but are not limited to, reliability, maintainability, human factors, technical publications, components, and system engineering, all of which are separately managed groups having specific duties.

Present analysis data[1] requires three days (8 hr/day) to obtain results which are often lacking in detail and incomplete due to time and data constraints.

The effort of this research is designed to develop a computer mathematical model which will fulfill the need for supplying quantitative data for proposal response, special studies, and provide quantitative management decision data in a more timely and efficient manner.

This model will provide further depth of analysis, than at present, due to the elimination of manual calculations and decisions. It will provide a timely response to the various task requirements as well as being flexible enough to include alternative data for management consideration. The model will not only simplify the present task effort and reduce time, but also incorporate factors useful in meeting future anticipated requirements.

---

[1] This referenced analysis was for an end item having nine (9) major subassemblies. Computational analysis for the quantitative input to the study required a day and a half. This was preceded by another day and a half obtaining information and inputs from some of the other disciplines involved in the overall proposal. The analysis was performed by an experienced analyst and therefore does not include a learning period. Results of such an analysis are difficult to measure especially when they become part of an overall proposal by the company to obtain a contract award which is the basis of obtaining business in the military electronics industry.

CRITERIA

The research results will provide analysis data, similar to that mentioned previously in the discussion of present analysis data which required three days of effort. The effectiveness of the results will be measured using the following two criteria:

1. A computer analysis printout, and the time expended to obtain the data for developing the printout, will require no more than one eight hour working day.

2. A second computer printout, should it be required, representing alternative analysis data will not require more than one hours effort, once the original data requirements have been established. (The establishment of data requirements will be discussed later. The requirements refer to the comparative association of historical analysis data with proposed study data).

Chapter II

METHODOLOGY OF DATA COLLECTION AND ANALYSIS

Accumulation of historical quantitative data to be used as a basis for the mathematical model is one primarily involving the location and the transportation of the actual data available to the research. The analysis data was generated under government specification WRC-30 and General Dynamics Specifications FZM-12-1340, FZM-12-6340A, and MLA (Maintenance Level Analysis) data resulting from seven conferences conducted by the government, at this facility.

DATA COLLECTION

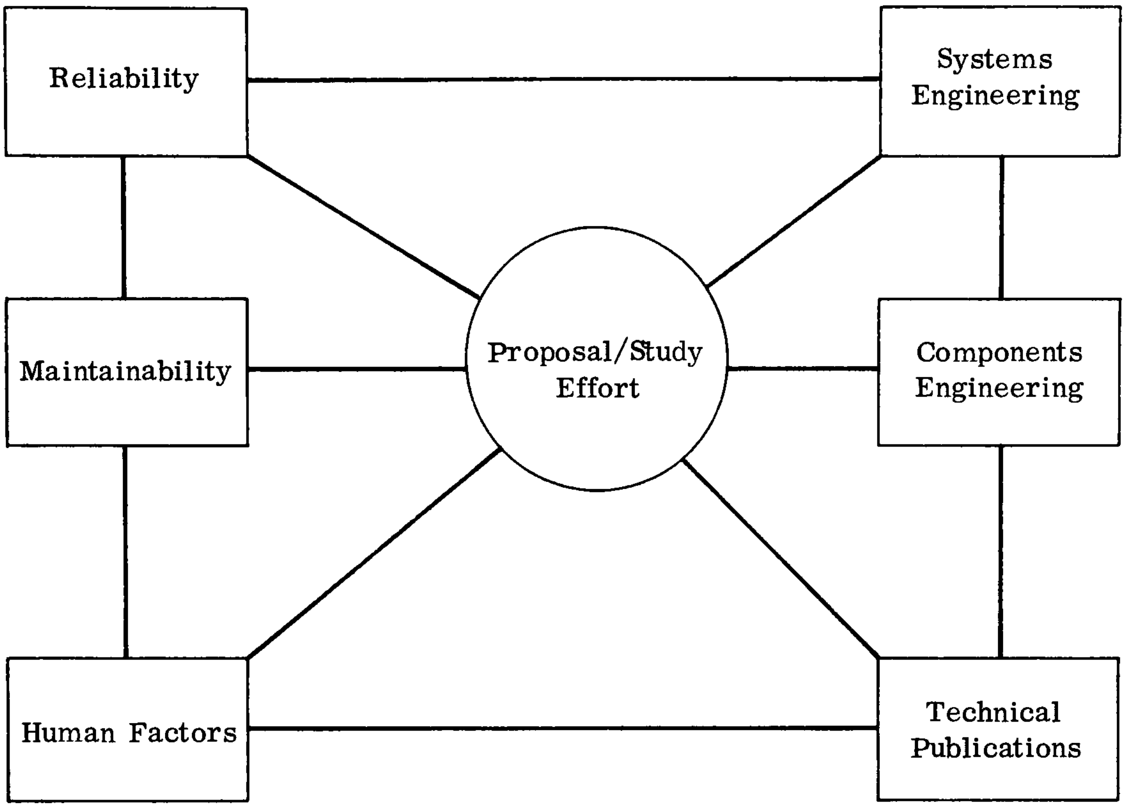
The bulk of the data was located in a General Dynamics storage facility here in the city. To obtain this data for analysis required written description as to the type of storage item requested, the identification numbers assigned to the applicable storage containers, as well as the name of the person requesting the data containers, and when and where the containers to be delivered. Having initiated this phase of data collection, it was then necessary to identify the data containers located within the company. Overall, the accumulated data records represent approximately five (5) years of data. These records were written for several maintenance shop configurations. Each shop configuration, in turn, has several systems for which detailed data has been generated.

Other data collection involved the solicitation of inputs from those organizational groups, previously mentioned, which collectively contribute to the proposal/study qualitative and quantitative inputs. As depicted in the Data Flow chart, Figure II-1, there is no one organizational group which does not depend upon interaction from the other data sources. This assures a good feed-back of data flow. The data flow chart also helps to point out the fact that any systems model that will aid the data generation and collection tasks will certainly be of value to the overall proposal/study effort.

DATA FLOW

The various organizational groups, depicted in Figure II-1, which use the analysis and study data were asked to express their recommendations for improving the present task requirements. The one main concern expressed, as a result of collecting recommendations, was the need for a shorter turn-around time for data accumulation and summary distribution. Each group, as expected, expressed the desire to have more information upon which it could act and thus generate the output for use in the proposal/study effort. The following will aid in acquainting the reader with the various interactions involved:

a. "Human Factors", requires such inputs as item description and environmental operation data. Their outputs consist of recommendations and specific criteria as related to the man-machine interface (The relationship between the tasks performed by the operator and maintenance man as related



DATA FLOW

FIGURE II-1

Figure II-1. Data Flow

to the particular machine or equipment. Thus the government has acknowledged the term Human Factors). Such output includes the identification and the location of the controls on the equipment which the operator will use, information relative to indicators and their operational height, and use of indicator light color as well as size and location. The desire by Human Factors for more data input includes knowing more about operational times, repair times and specifically the type of tasks anticipated. This data would certainly help them to provide a more detailed output to ultimately aid in determining equipment location and personnel training requirements. These items in turn are reflective within operator-equipment safety precaution warnings and other requirements relative to controls, maintenance tools, operator fatigue.

b. "Reliability", requires inputs such as expected equipment operating time per day, type of equipment used, and the expected equipment operating environment. Their outputs consist mainly of prediction reports which give the expected number of equipment failures per period of time — — usually per a 100 hour interval. They also generate a report titled FMEA (Failure Mode and Effects Analysis) which is used primarily by Maintainability. It can readily be seen that their desire is for more detailed information concerning expected equipment operation and components within the item assembly. This added information would result in a more specific prediction report.

c. "Systems Engineering", require inputs relative to expected equipment operating life, anticipated maintenance requirements both preventive and corrective, and expected personnel requirements. Their outputs help define equipment operating parameters which will tentatively meet the proposal/ study requirements. Their need for more details, as well as information relating to actual analysis data which is supported by backup figures and documents, will certainly enhance their efforts of response. Whenever a respondent to a proposal or study can refer to similar task efforts in which he has participated, this experience factor goes a long way toward weighting his ability to perform the task proposed.

d. "Components Engineering", like the other organizational groups, requires data concerning equipment type, quantity, environment, and usage. Their outputs refer to recommendations relative to equipment standardization, reliability of use, as well as keeping up with the state-of-the-art design techniques and components. Additional data inputs relating to component use, quantity, and overall design complexity will aid in identifying those items presently used, or new to the technology field, which will fulfill the overall design requirements being imposed.

e. "Technical Publications", requires inputs relative to maintenance requirements, both corrective and preventive. These inputs include expected component quantity and expected frequency of repair or replacement. Their output, in turn, helps to define long lead times for purchase, type of manuals to be supplied with the equipment, and also aids in identifying components which are presently in the military federal stock category. This knowledge helps define the supply methods and channels to be recommended.

f. "Maintainability", requires the prediction reports and FMEA data from the reliability group. Other inputs include expected design parameters, equipment use and environment, as well as component and personnel data. Outputs primarily consist of the quantitative maintenance task requirements and intervals. The outputs aid in defining design criteria to be incorporated in the specifications as well as supporting data relative to component use, quantity, and expected mode of failure. The need for more detailed inputs relative to equipment complexity, type and quantity of components, and the expected mode of operation and failure will result in a more detailed prediction, the more realistic and informative will be the data in the resulting system analysis.

METHOD OF ANALYSIS

The above description of the various input and output needs forms the basis of analysis. It is impossible, or more aptly, impractical, to supply all the data required by each organizational group and to supply it for each proposal or study. And no two proposals or studies are alike so that a uniform method of supplying data is acceptable. Therefore, it was necessary to consider the outputs of each group and to see if there was a common need. Also it was necessary to determine if there was a consistent pattern as to the type of data to be supplied. As expected, there was a consistent pattern and data flow upon which most proposals and studies are based.

The recommendations received from the various organizational groups as well as the data which was physically collected were thoroughly reviewed. One of the first questions, which required data analysis before answering, was whether the volumes of historical quantitative data contained data related to present data requirements. The analysis showed that the data was quite plentiful as well as adaptable for proposal and study orientation. The data contained information which described various design considerations which had been investigated as well as a description of the item's functional use, maintenance requirements both recommended and required, personnel requirements, and also gave the reason explaining the choice of the various maintenance concept requirements or recommendations.

Another question or point needing analysis was the consistency of the data as related to a common reference point. The data was found to be in terms of hours when relating to MTBF, MTBMA, and the various other operating measurement rationale. Component failure rates were in terms of failures per 100 hours of operation and in other cases were expressed in terms of failures per hour of operation. The conversion of this data to a uniform reference base was a simple task and did not change analysis results. One other area which contained a different reference base was when some of the more recent data was quantitatively based upon an eighty (80) hour work week. This 80 hour data base was a result of customer requirements. In any event, this difference of baseline required that the data be converted to a forty (40) hour baseline. Conversion of all data to an 80 hour base would have been feasible however, practically all requirements use a 40 hour base. The 40 hour base will then be the baseline for the research.

Some of the more detailed data forms enable further understanding of the reasons and methods of determining the various maintenance tasks and overall item concept. The older data contained individual itemization of components and the task time associated with each component such as fault isolation time and repair time. The newer or more recent data depicts, in logical flow chart form, the various isolation tasks required to locate a malfunction item. The flow chart also indicates the type of corrective action to be taken following localization. This data in itself is the type of data required by proposals and studies. However, it is only possible to supply this data for an overall item, which many people refer to as a chassis assembly, and does not include details on subassemblies and piece parts. The detailed analysis which includes the piece parts and subassemblies within an end item is prohibitive when the study is only in the conceptual or proposal stage. The application of historical data will help fulfill this data requirement. (Some of the different forms, upon which the data was recorded, are to be found in Appendix A.)

The comparison of the detailed data form with the logic flow chart resolved the question of consistency of data and maintenance measurements. Tasks depicting similar events such as repairing subassemblies or removing and replacing piece parts had a small variation in time and failure rate factors between the two types of data forms. For example, the older data may require nine (9) minutes to do a task which the newer data may represent as requiring eight (8) minutes. The same analysis could also be reversed. Some of the task time determining factors would be the overall item complexity and the method of item installation as related to the location within the overall circuitry. The major significance here was that the data showed consistency in depicting task requirements and time intervals when referring to similar items. This factor is very important.

DATA RETRIEVAL REQUIREMENTS

In an effort to fulfill the need for data for proposals and studies, it was necessary to review the requirements presently used. Figure II-2 is a Maintainability Prediction Worksheet. This worksheet and its continuation sheets, represents one of the main types of quantitative data inputs to proposals and studies. The inputs, as previously defined, represent an accumulation of data from various organizational groups.

A brief description of a typical sequence of events in preparing a proposal submittal will help the reader to understand the method of data retrieval determination. For example, the proposal or special study is requested by the Contracts Department. (A special studies requirement may also be initiated within the company.) In any event, the responsibility is assigned to a project engineer who will coordinate the necessary technical task efforts. The task requirements are defined in terms of responsible project areas and then the project engineer and/or his staff will set up milestones using the

GENERAL DYNAMICS | ELECTRONICS
ROCHESTER

MAINTAINABILITY PREDICTION WORKSHEET

IA CONTROL NO. ______ PART NO ______ NOMENCLATURE ______ SHEET OF

ITEM	DESIGNATION	NOMENCLATURE	FAILURE RATE (λ)	AVERAGE TIME TO PERFORM CORRECTIVE MAINTENANCE TASKS							T_r	M_c
				LOCALIZATION	ISOLATION	DISASSEMBLY	INTERCHANGE	REASSEMBLY	ALIGNMENT	CHECKOUT		

ENGINEER ______ DATE ______ 19 ______

M_{c_t} = SUM OF M_c's

FORM 1135E 5/63

11 44

Figure II-2. Maintainability Prediction Worksheet required proposal response time requirements as a guideline. (Usually the requested response time is so short that task definition is not fully defined. In this case the incoming request is studied to determine what project areas are involved and then each project area will be given a complete copy of the request.) Depending upon the time response, a meeting is held, with all concerned project areas represented, to discuss the requirements and to clarify any anticipated problem areas. The responsible areas then pursue their tasks. As expressed earlier, there is considerable interaction among the various areas. One of the major time elements involved in responding to a proposal is the time required to define the types of equipment needs and the parameters to satisfy the request. Mixed with this is the composite of electrical operating constraints, the overall mechanical configuration, the total weight limits, and time and cost factors. The success of a response is dependent upon many factors which are all interrelated.

This interrelationship of quantitative factors was evident in Figure II-1. The recognition of this need for timely and detailed data helped to determine the data recall program requirements. Each organization group needed to know the type of equipment involved, the complexity of operation, and this need in turn is reflected in the overall system breakdown into subsystems, assemblies, and piece parts. Each breakdown of the system is then concerned with the operating requirements which in turn is reflected in the equipment reliability. The equipment reliability is affected by the design, operational use, environment, and by the recommended maintenance concepts. Each of the above dependent items forms a building block in the generation of final analysis data. The data flow depicted in Figure II-1 may require several cycles before arriving at an acceptable analysis. However, this cycling event is time consuming and thus in many instances cannot be continued to an optimum because of the time response factor.

The data recall requirements therefore put emphasis on defining those quantitative factors which serve as a basis for defining other data items. These factors included MTBF (also called failure rate), MTBMA, MTTR, and corrective maintenance time. The historical data records, upon which the data research was based, were in various formats as depicted by the sample forms in Appendix A. Each of these forms was studied in an effort to determine the depth of analysis which was required to complete the form. Such an analysis aided in determining if the data content represented the efforts of basically one organizational group or if there was total group interaction requiring feedback and tradeoff studies in which each had an opportunity to effect change and thus arrive at an optimum solution. Familiarity with data content will readily show whether one organizational group dominated the generation of data. If such were the case then it would be necessary to re-evaluate the data and arrive at an optimum solution which was not so void of other group design parameters. For the most part, each form necessitated the intergroup participation.

Trade-off study is very important. Each new design must go through phases of detailed discussion and analysis so as to optimize all the interrelated design parameters. It is the desire of every engineering organization in industry to define all requirements in the initial system specification. The hope is then that no (or minimal) change will be required. Each change is costly in time, money, material, and of course, to management scheduling. The later in the production phase that a change is made, the more expense involved. In the extreme case a complete scrappage is required and assembly must start over again.

The reader can now understand the need and desire by each organizational group to have more data, thus effect a more detailed analysis and to ultimately be more responsive to proposal and study requests. Technology, economics and the state of competition demands data output which represents the company's capability to meet the design requirements imposed by military contracts.

INPUT/OUTPUT DATA FORMAT

To meet this need for data which represents detailed studies, interaction, and optimization of design parameters, the historical data was collected. The major quantitative data entries were compared to the present prediction request entries. (Appendix A and Figure II-2). This comparison was made so as to answer the next question concerning data retrieval. This question which had to be considered was the determination of a format which could be used to submit the historical data for computer programming and also the format for data retrieval. The selected data printout should be such as to simplify the reading of the data items. It was decided to have a one hundred thirty-two (132) character printout format from the computer program. This means that to maintain an easy to read, one row entry of data, that the format is limited to 132 characters (alpha/numeric symbols) of print.

Restriction to one row of data is not really a constraint which must be adhered to because there are other methods of printout such as printing several rows of data. However, the one row concept facilitates the reading of the data entries and also permits using a format with headings under which the various data entries are delineated and easy to locate. This is even more evident as the number of data entries increases.

The resultant format for transcribing the historical data for use in the computer program model is the same as that specified for the data printout. Figure II-3 is the Input Data Format sheet used for data inputs. Interface with the Program Data group was necessary in order to establish the feasibility of computer programming initiation and adaptability to present company computer facilities. The format number is assigned by the Data Forms Control group within the company. This number is a document control number and must be used when requesting copies.

Briefly stated, the form is in three basic headings. There is the Header Information such as part number, etc., then the General Data which contains those data entries used most commonly by various organizational groups, and

P/N & NOMENCLATURE	SYS OR TRU	CSC OR CGD	CONT MODE	GENERAL DATA: MTBF HR	MTBMA HR UNSCHED	MAINT MAN-MIN PER OPER. HR	ACTIVE DOWNTIME MINUTES: UN-SCHED	SCHEDULED TIME	SCHEDULED INTERVAL	DET... MAINTENANC... UNSCHEDULED (MIN.): TR_A	TR_T	REPAIR	R/R	R...

Figure II-3.
Input Data Format

DETAILED DATA

...INTENANCE TASK DATA (...MIN.)					SPECIFICS	
		SCHEDULED			REPAIR TIME	MAINT. FACTOR
R/R	F.T.	MINUTES	INTERVAL	CODE	MIN-MAX	MIN-MAX

then the Detailed Data which reflects in more detail those entries under the General heading. The details of how and where to apply the individual data entries will be contained in a separate Procedures and Instruction manual to be generated and distributed to the various project groups.

DATA RETRIEVAL EQUIPMENT IDENTIFICATION

To be able to effectively use the historical data requires a preliminary identification of equipment. The first step of the proposal or study response is to identify, as has been the case before, the type of system required and the basic type of equipment from which the system will be made. This identification includes the basic operational characteristics such as power requirements, mode of operation, voltage and signal stimulus devices, control and relay transfer units, and measurement and indicator devices.

As stated previously in Chapter II, there is a proposal meeting held with representatives, from each project group, who will be required to respond to the particular proposal or study task. It is during this meeting that the identification of system requirements is made. The meeting attendees relate the proposed requirements with other system items being worked upon now or in the past. Therefore, it is the pursuit of this reflection or recall of similar items which must be encouraged. To maximize the use of historical data, someone must be able to recognize the present needs and associate this with available historical data. There are several sources of information available which will aid in this identification of similarity. (Usually each project group has some source of data which is more relevant to its needs than other sources and therefore no attempt will be made here to list these references for each group.)

To better enable an identification of similar equipment, a list is to be supplied at each proposal meeting which delineates the part number and nomenclature of each item in the historical data records. This list should be kept up-to-date as more information is accumulated. This list represents all the items which will be in the historical data model both as a result of this study and as a result of any further recommendations to this study.

This research also considered the possibility that at sometime, someone may not be able to make a comparative identity by part number or name, between a proposed item and one on the above referenced part number listing. Therefore, another list Table II-1 was generated after an analysis was made of the historical data items and the various proposal and special study request items. This new list consists of equipment classifications. The number of classifications was purposely kept minimal to enable rapid equipment identification. Therefore, if an identity cannot be made by item part number or name, then it may be done by equipment classification. In addition, each classification was further defined and divided in subclassifications. Table II-1 is the Equipment Classification List and represents the class and sub-class of each equipment which is applicable to the model and will aid in responding to proposals and studies.

TABLE II-1

EQUIPMENT CLASSIFICATION LIST

1. Stimulus Devices

   (a) Power
   (b) Signal
   (c) RF
   (d) Microwave
   (e) Infrared
   (f) Synchro & Servo
   (g) Radar

2. Measuring Devices

   (a) Microwave
   (b) Pressure & Temperature
   (c) Control
   (d) Ratio, Standard, Comparator
   (e) Multimeters
   (f) Scopes
   (g) RF
   (h) Audio
   (i) Recorder

3. Interface Device

   (a) Terminal & Distribution
   (b) Adapters
   (c) Control
   (d) Signal

4. Switching Devices

   (a) Relay Assembly
   (b) Signal & Power Select & Switch

5. Display Devices

   (a) Power
   (b) Test Data

6. Control Devices

   (a) Microwave
   (b) Relay (Switching)
   (c) Power
   (d) Indicator
   (e) Signal
   (f) Program
   (g) Temperature
   (h) RF

7. Simulators

   (a) Flight Control
   (b) Mechanical Movement
   (c) Receiver Transmitter Systems (Includes Antenna
   (d) Radar
   (e) Navigation
   (f) Loads

Chapter III

ANALYSIS OF RESEARCH

Chapter I defined the purpose of the research study as well as explained the use of analysis data. Chapter II described the type of data studied, analyzed the data and inputs that were available, and then adapted the data for computer program modeling. It now remains to be determined whether or not the research proposition is supported as specified by the measurement criteria.

DISCUSSION OF DATA ITEMS

To adequately relate the study findings to the purpose for which the research was undertaken requires a step by step analysis of the various data items which are incorporated within the system data model. This analysis can be easier understood by referring to the different data headings depicted in Figure II-3.

Establishing the scheduled maintenance (also called preventive maintenance) tasks, task times, equipment, and personnel needs, aids in defining the overall equipment availability. This is an important factor in responses to proposals and studies. Equipment availability is an important factor when making decisions relative to time, cost, and quantity. Now most scheduled tasks refer to meter calibration, cleaning of air filters, removing measurement equipment such as oscilloscopes and any other precision calibration standard from the system, and then replacing these equipment items with recently calibrated items. All of these calibration requirements are such that the calibration accuracies must be traceable to the National Bureau of Standards in Washington, D. C. The task time to perform the calibration of equipment is usually defined within certain limits. The only exceptions which would be evident are those involving the accessibility to the item within the particular system and also the availability of the necessary calibration support equipment. Some systems contain equipment which requires very little calibration while other systems require considerable calibration. The amount and type of support equipment needed to perform the calibration task(s) varies from system to system. (The reader can refer to Military Specification MIL-C-45662A, Calibration System Requirements for more information on this topic.) It was found that the historical data provided a good base of data for reference and the consistency of the data was such that it was readily adaptable to the data analysis model. In fact, this historical scheduled maintenance task data provides a firm basis for establishing proposal and study data as it has fulfilled the requirements of various military specifications.

Having determined the applicability of scheduled maintenance data to the model it is then necessary to consider the unscheduled maintenance data.

Repair times for removing piece parts from an assembly is usually compatible from equipment item to equipment item. Any relevant variation in task time would be primarily due to the gaining of access to perform the particular task of repair. The variation of access times can be quite pronounced when no consideration has been given to performing a system analysis. However, the historical data as applied to this research analysis model represents many systems' analyses and thus the time variation is minor. It is quite evident that time and task weighting of several items, over a period of time, for several systems and subsystems, will eventually show a quantitative relationship. This quantitative relationship has also been recognized by the military. There are military documents listing many items which have been studied over a period of time and which relate to actual military shop practices. In this respect the military recognizes that there is some sort of standardization among similar types of equipment. (The reader is referred to Air Force Manual AFLCM-65-1 Electronics Maintenance and Repair Policy for further reading.)

Where the real element of time difference is significant is in the fault localization and isolation tasks. To help simplify the understanding of this difference, consider the task of localizing and isolating a power failure in a car, a locomotive, and an airplane. Assume that localization of the malfunction has been made by the fact that the car motor has stopped or the jet on the airplane has stopped or the locomotive has stopped. Actually in electronic equipment this localization is not so apparent. Many initial malfunction indications are only an illuminated light which should not be on or vice versus. Once localization has been made, it is then necessary to isolate the cause of the failure. Suppose each of the items has a power failure. The complexity of design and the power requirements of the three items demands different maintenance approaches. For instance, consider a maintenance man isolating the power failure on a car. Assuming that he has had experience or knowledge in a similar car instance in the past, there is an experience factor which will aid his maintenance tasks. Further support of this is evident when an auto repair shop supervisor opens a maintenance manual and states that the standard book time to repair a particular failure requires so many minutes. This book time is a weighted standard which has been achieved over a period of time. This standard is still subject to variation but, the variation is not as far from the weighted standard as an estimate made by someone without background data and experience. And this is important because the person requiring the services of the maintenance shop personnel may very well want a good estimate (analysis) before deciding whether to repair the faulty item or buy a new one. This is where trade-off studies are very important in helping in the management decision processes and the need for experience data is important.

It is this basis of data accumulation and the relevancy of the similar types of equipment items that strongly supports the application of historical quantitative data for use in a system data model for better responding to proposals and special studies. The accumulated historical data not only represents analyses of actual types of equipment, but also bears the application and incorporation of many design considerations and trade-off studies which were required to approach the optimum system analysis as reflected within each analysis used for the system model. The application of this historical data and its many design aspects outweighs data which lacks experience factors and information which must be obtained and/or estimated within a limited time period.

The proposal or study response, as previously stated, must not only be timely but contain data which most accurately reflects the anticipated characteristics of the proposed system. Two points are made in the utilization of historical data which aids in assuring that realistic data has been provided. One is that the data is existing and not simply an estimated factor. Two, the historical data reflects actual, rather than fictitious items and can be further supported by available documents such as drawings, etc.

SPECIFIC MODEL APPLICATION

Having discussed, in Chapter II, the type of historical data available and having related the purpose for which the data items are used, it is now easier for the casual reader to read and understand an actual computer printout of analysis data.

To provide a basis for discussing the criteria, as defined in Chapter I, a trial computer printout was obtained. This printout, titled Newsystem Simulation, is found in Appendix B of this report.

In an effort to compare the research model application with a situation using previous analysis methods, a proposed new system was simulated. It will be remembered from Chapter I that an analysis involving nine (9) major subassemblies required three days of analysis time. This referenced analysis was also subject to time and data constraints as well as possible biased decisions on the part of the analyst.

Past data indicates that the majority of systems contain, as a minimum, a power control panel, switching devices, a system operation control panel, measurement devices, a power supply, a signal generator, and a cooling fan. This research study proposed a n ew system simulating nine (9) equipment items. The types of equipment simulated are self evident upon reading the printout in Appendix B. (The only items not readily recognized, by the casual reader, are the words DATAC and CONT. TP. DATAC is the main operational control panel. CONT. TP is a test point switching device.) This new system closely approximates those system requirements referenced in the analysis requiring three days.

The time required to identify and associate the proposed nine items with a similar item having historical data, required four hours. It is believed that this time could have been shortened had several people been involved in the equipment identification and selection. It is the opinion of the researcher that the task of associating proposed items with historical items will be performed at the various proposal meetings previously mentioned. The task time required for item association should then be reduced.

Once the particular historical data item was selected then the data relevant to each of the nine items was adapted to the computer input format (Figure II-3). The data sheet was then taken to data processing to key punch the data cards to be used by the computer. This key punch task required forty (40) minutes by the researcher. However, it is believed, based upon actual data, that an experienced key punch operator would have required approximately ten (10) minutes to do the same task. Both of these times are given to provide an idea of what may be involved when there is a more lengthy request for data.

The person requesting a computer printout of analysis data must consider various other factors such as shared use of the keypunch machines and whether or not he plans to prepare the data himself. If he does not do the keypunch himself, then he must consider waiting time when requesting the work be done by an experienced operator. Some tasks have priorities and in those instances the time factor could be less. In any event it has been mentioned here as an item to be considered.

Waiting time is also a factor when obtaining an actual computer printout. This waiting time is the period when the keypunch cards are presented to the computer programmer until the time the actual printout is received. Once again, there are other company requirements which demand computer time and each has its particular priority as well as computer usage time.

APPLICATION OF MEASUREMENT CRITERIA

Returning now to the Appendix B computer printout it is seen that there are nine items within the simulated new system. All the pertinent data such as MTBF, MTBMA, maintenance times, availabilities, etc., are printed in a form which may be directly incorporated as an Appendix or Attachment to any proposal or special study. The data is also delineated so as to facilitate reading as well as rapid item identification which is especially useful when several people are discussing the particular data items prior to making management decisions.

Note the availability data on the second page of Appendix B, the two items next to the last. For example, the Ai, Inherent Availability, is 0.99745. This means that the new system, comprised of the nine major subassemblies, is expected to be operational 99.74% of the time. The other 0.26% of the time the system is expected to be inoperative due to unscheduled maintenance. Earlier, scheduled maintenance tasks were discussed. These tasks require that the new system be removed from functional use. The Aa, Achieved Availability, is 0.99328. This means that the new system will be removed from operational use, due to scheduled and unscheduled maintenance, 0.67% of the time. Many proposal and study requirements set a design goal which will realize a 90 to 98 percent Aa. From the presented model data it is evident that the new system with the nine major subassemblies shown will in fact meet the availability requirements. The other data items, as defined in the printout, aid in the computation of the availability factors. The particular equations are referenced on the printout, however, all computation is performed by the computer and eliminates human computational errors.

The actual time required by the computer to perform its task, which includes reading data cards, performing computations and printing the actual output in Appendix B, is printed on a separate data sheet. In other words, the computer output not only provides the desired printout but also provides a list of the various programming steps as well as a data entry which shows the actual computer time. This time entry is used by the company in its records relating to data processing. Exhibit B presents only the printout of the analysis data and not the other sheets because they are not pertinent to the research. However, it should be noted that the actual computer time was 3 minutes and 44 seconds.

Measurement criterion No. 1 stated that a computer analysis printout, and the time expended to obtain the data, would require no more than one eight hour day. The actual printout in Appendix B required four hours of item identification and association, forty minutes of preparing the data for computer use, and four minutes of actual computer run time. This is a total of four hours and forty-four minutes which is well under the eight hour criterion. (There was an actual waiting time of one hour before the printout was actually received. As stated previously, this time can vary, depending upon a number of items). Waiting time has not been included in the total time measurement of meeting criterion No. 1. If it had, criterion No. 1 would still have been satisfied.

The second measurement criterion stated that a second computer printout, should it be required, representing alternative analysis data will not require more than one hour more effort once the original data requirements had been established. Another computer printout with alternative data was not actually obtained. However, assume the most complicated case wherein all nine of the items were to be replaced. This would in effect be another new system simulation. Therefore, it would be necessary to spend forty minutes preparing the data for use by the computer. It would also be necessary to obtain another computer printout which would require another four minutes.

The total time to provide the second set of data to facilitate proposal or study efforts would require approximately three quarters of an hour. This time is less than that stipulated in criterion No. 2.

Thus, the two measurement criteria are met and the proposition, as stated, for the use of historical data, is supported.

The reader can see where the use of alternative data is simplified by using the model. The major task is in the association of historical data with data required by the proposal or study. The task of association is hopefully aided by the listings described previously in Chapter II.

Chapter IV

LIMITATIONS

As with most models, there is a limit to their capability. If this were not so, then there would certainly be a universal system model available today.

A complete appraisal of this research study and its useful application will never really be possible. The application of historical data can be applied to a model for obtaining analysis data. A data printout has been obtained which represents a systems analysis and as presented in Chapter III this data is obtained in a shorter period of time than at present. However, the total effect of this data when responding to proposals and studies will not be readily evident. Should the proposal and study effort result in a contract award, it can only be assumed that the entire team effort was responsible for the success and not any one specific data input.

This model must assume that the data generated within the historical records was developed by personnel who were conscientious in their task and to the task detail. Analysis of the data tended to show a consistency of analysis throughout all records which contained many different names of the people who prepared the data. This assumption must be maintained when any future data is made available for study. The concept of biased analysis data must be omitted so as not to have computer results which reflect unrealistic quantitative factors. The continued use of historical data will establish a uniform reference base.

As the research progressed, the necessity became evident to be better able to associate those items under consideration, in the proposal or study, with similar items in the historical records. It was resolved that this problem would be aided by providing a complete listing of those items within the data system. At present, the organizational groups participating in the various proposal or study activities meet to clarify understanding of the task and equipment involved. At this meeting an understanding must be reached concerning the item in the historical records which most nearly reflects the item under consideration in the proposal or study. And if this common agreement upon a "one for one" association is not possible, then there is the capability to select two relevant items and thus have alternative data printouts which would be used in the final analysis.

There is no indication that personnel experience and turnover will ever reach the point where no one will be able to associate a proposed item with a similar item in the historical data listing. In the event that such a situation does arise, then there are records within the company which describe the basic operational function and parameters of individual items.

Some of the various data entries as they appear in the final analysis may require some mathematical manipulation to put them in the form used for a particular task. This however, is a minor point which should be recognized and is not expected to have any detrimental effect.

Another limitation is the descriptive data which supports the quantitative data. It is not part of this research to provide descriptive data but as previously mentioned, the data is available in various forms, the most pertinent of which is the MLA form available in the Maintainability group.

Two other items which became evident, during the research data collection and the solicitation of inputs from the various groups, were item cost data and equipment weight. These data inputs are not really limitations to the study but rather limits to details desired in a particular area. The resolution was that weight requirements are usually specified as a design parameter and a comparison with recorded data could readily be made during group discussions or by referencing back to the above mentioned MLA data. Cost factors were definitely omitted for several reasons, two of which are: (1) the computer printouts will be used by people outside of the company employ and cost factors should be withheld; and (2) the cost factors will not necessarily represent that of a new item. However, cost data is available should its use actually be required for management decision making purposes.

Chapter V

APPRAISAL OF RESEARCH STUDY

In Chapter III, it was pointed out that the use of historical data could be adapted to proposal and study requirements. The ways in which the various items under study could be identified with historical data items was also presented. The limitations to the use of this system data model were presented in Chapter IV. Now that the model has been presented, are there areas for expansion; how does this application of historical data compare with those discussed in other literature readings; and most important, what is the value of this model as a management decision making tool?

AREAS FOR EXPANSION

It has been brought out, as a result of this research, that a method to improve item association would greatly reduce time requirements for analysis response. The equipment classification list, Table II-1, has fulfilled part of this need, but improvements are still possible.

Another area which is already under study is the situation which exists when no similar equipment association can be made for one or more items. In this case, new analysis data must be generated. The possibility is presently under consideration to develop an alternate program which will utilize new analysis data and historical analysis data. The intent is to have both data inputs programmed such that an output, similar to that depicted in Appendix B, is obtained. Such a program would greatly increase the flexibility of supplying analysis data for proposals and studies.

No doubt many other areas of improvement can be recommended. For example, the storage of all historical data on a computer tape would greatly enhance computer program model capabilities. From this data expansion, the user can initiate new programs to manipulate this data and result in different types of output which would be more adaptable to specific study areas. The present data format considered this feasibility when deciding format and data content.

COMPARATIVE LITERATURE FINDINGS

There are volumes of computer programs and libraries full of studies dealing with applications of business techniques and the manipulation of various business data. This research study therefore is not setting any precedent in applying data to mathematical models. What it is doing is using available data in a subjective manner, to facilitate task expediency and applicability.

The use of the historical data and its continued enlargement and availability requires that a Procedures and Instruction manual be prepared for use by the various organizational groups in the company. As an insight into what should be in the manual, and in turn associate this with the data analysis and research study, various readings pointed out several factors to be considered.

Leslie Matthies[2] in his book on systems manuals points out the need for a well defined manual and at the same time warns of some of the common errors which evolve. Considering that a single report can cost several hundred dollars a page just to plan, write, and distribute, it is then with appropriate concern that any manual and the purpose for which it is to be written be clear and well defined in order to convince one of the advisability of its usage. This clarity and definition must also be reflected in any computer model data recall capability and structure of output printed format. For example, the main data entries (General Data) depicted in Figure II-3 contain a prime position in the row of data. The less significant data (Detailed Data) is tabulated after the main data entries. Management is generally concerned with the overall data (General Data) more than the detailed data which is used to present the overall picture.

Management Systems[3] pointed out several aspects which were found to be relevant to the present study. The authors stated that the life cycle of a management system consisted of three states: (1) the study and design of the system, (2) its implementation as a new system, and (3) its operation within the organization for which it was designed. They went on to say that most

---

[2] Leslie H. Matthies, The Systems Manual (Colorado: Systemation Inc., 1967).

[3] Thomas B. Glans and others, Management Systems (New York: Holt, Rinehart, and Winston, Inc., 1968).

literature concerns itself with the latter two stages. The reason is that the computer promises such great benefits that management is only concerned with these benefits and not the initial study and design.

Once the decision is made to go ahead with a project, then the urgency is sometimes such that maximum productivity is often lost in lieu of a secondary productive operation. There is also considerable difficulty in drawing together an appropriate tested body of data concerning the study and design of systems. When management of the Product Assurance department, in which this research study was done, realized that a wealth of data was available which could be applied to a computer system model, there were several immediate requests for data. However, restraint was fairly easy, due to the infancy of the study, to subdue the requests with a promise of keeping those involved up to date on progress and findings. The research progressed faster than anticipated due to several reasons: the first is management's urgent desire for data results, the second is the researcher's familiarity with the type of data involved, and third, the desire to test the proposition of applying the historical data to present needs.

Other divisions within General Dynamics have embarked upon computer math models. However, one model was mainly of the physical associative type which establishes a work unit code for an individual item and then relates this item to any of several other assemblies of which this one item was a part. Another model also gave an itemized breakdown of the assembly. This type of data breakdown is similar to cataloging and preparing an illustrated parts breakdown for spares requirements. However, the major task in this research study of historical data was primarily that of data collection, establishing data availability versus data recall requirements, and to establish a uniform data format. Figure II-3 was designed with this concept of readability both by the individual inserting data in the program as well as the person receiving the data printout for analysis. The intent was to provide an informative math model, and to keep it such that its data content was self descriptive to the user. The data are also to provide a common base for communications among the various organizational groups. This composite intent added to the overall attempt to increase data availability, data use, and to ultimately being better able to respond to proposals and studies.

The need for simplicity and a common data baseline is evident in practically all proposals and studies. The United States Air Force in an effort to standardize contractual obligations in specifying systems engineering requirements has published the AFSCM-375 series[4]. To quote from one document, "The system engineering management process encompasses the early identification of (1) AF system objectives, (2) the "design to" requirements necessary to meet these objectives, (3) the "build to" requirements which prescribe the ultimate configuration of the system to be delivered to the user, and (4) the requirements for personnel, training, procedural data, and logistic support".

---

[4]AFSCM-375 is the U. S. Air Force series of documents designed to help specify the requirements of systems engineering, documentation procedures, etc., as applicable to the Air Force.

This requirement for standardization is only part of the ever pressing need for immediate data and information which will represent the final product yet to be built. Reference to various military documents will clearly point out this need which is becoming more prevalent with each proposal or study request. This research study will by no means handle all the requirements specified, but will certainly provide relevant data, at a timely interval, and in adequate detail to support the management decision processes.

There are, within the company, failure reports which contain data relative to actual military experienced repair tasks. These reports have been received from various military bases, at which the equipment represented in the historical data is actually in use and maintained by military personnel. These data reports are just beginning to be received in sufficient quantity to enable some availability calculations using data obtained under actual use and to be able to compare these values with the predicted analysis data. Table V-1 shows the measured and predicted availability of five different systems.

TABLE V-1

SYSTEM AVAILABILITIES

SYSTEM	MEASURED	PREDICTED	% DIFFERENCE
1	0.874	0.948	8.4
2	0.884	0.956	8.1
3	0.927	0.960	3.5
4	0.991	0.996	0.5
5	0.946	0.977	3.2

As the table shows, there is really little difference between the measured and predicted system availabilities. This tends to show the effect of performing a good preliminary analysis. Additionally, as the equipment is used for a period of five years, it should have a higher measured availability. This can be seen in the Equipment Availability graph shown in Figure V-1 which represents a typical plot of equipment availability. During the initial period of use the number of failures is high, this is called "the de-bugging phase". As this phase passes then there are fewer failures, and thus a higher availability. As the item approaches obsolescence, the number of failures start to increase. This is true with many items today. For example, an automobile tends to have more failures as it gets older, and so it is that each item has a different life cycle and availability graph. There is no availability graph which represents all equipment items due to many factors, some of which are the item's actual use, its operational environment, functional complexity, and type of people involved with the equipment.

In an effort to establish an equipment classification list, several sources were investigated. The company's Contracts Department was asked if it used any method of classifying various equipment items. It had none which were applicable to the research use. Components Engineering had no list as such; its data usually directed one to a specific item, rather than a category of items. To use this method would be impractical with the intent for which a list is needed here in this study. Therefore, Table II-1, Equipment Classification List, is the researchers list which minimizes the overlapping of equipment types and provides for easier equipment reference. In the other reading data investigated, there was no reference to any equipment classification which had been used in guiding the establishment of a math model.

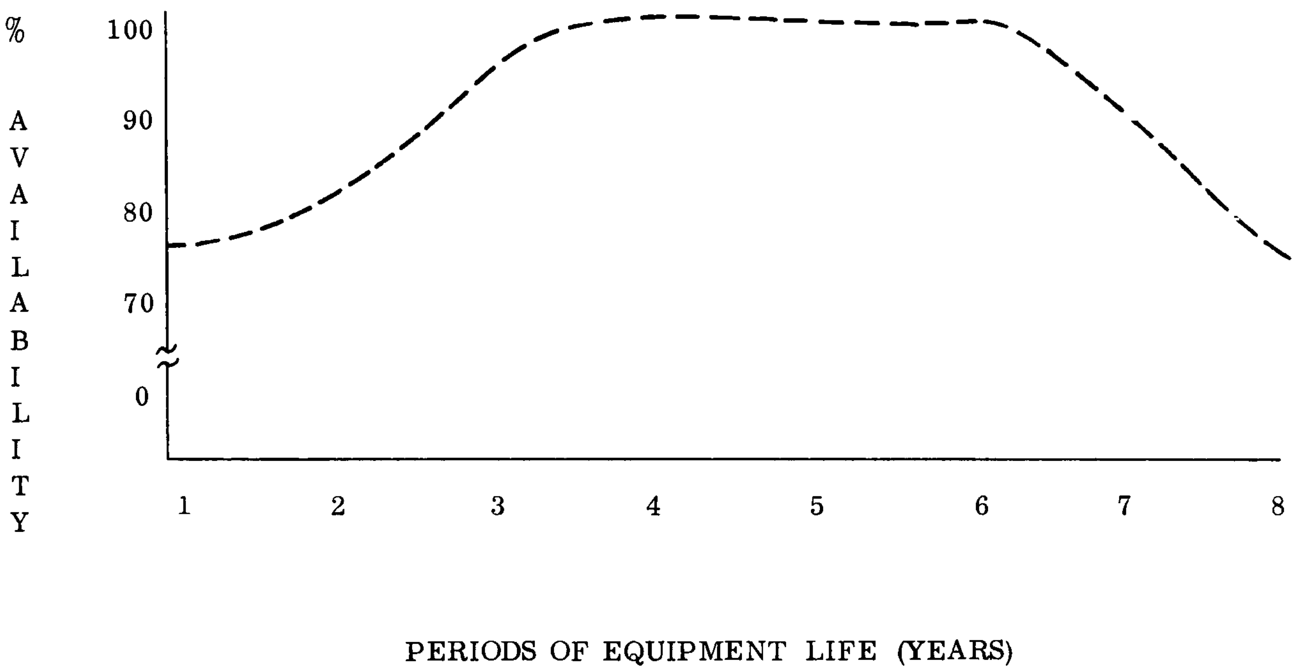


Figure V-1. Equipment Availability

MANAGEMENT USE

The purpose for which this research study was made and the resultant data support the fact that the model has implicit benefits to management. Today's business environment demands computer applications. These computer applications not only show that a company is using modern management tools but also enable the use of more data, in a variation of requirements, and in a much shorter period of time.

Speaking generally, management always tends to be under time pressure. Management must be able to respond quickly to any business problem confronting it. Management is not evaluated solely upon what it knows or how much education and experience it has. One of the most important aspects in managing is the ability to utilize available experience and data resources, associate these with criteria established and ultimately make a decision which fulfills company goals.

The computer printout obtained as a result of this study had immediate effect upon the department in which the research was accomplished. It proved that efforts within the department, when responding to proposals and special studies, could be accomplished more timely and efficiently. The computer printout presently provides management with a better tool to make decisions. There also is the realization that alternative data can be obtained to aid in making decisions. The model also provides a method of data storage which permits rapid data recall and eliminates the time consuming task of sorting through many documents.

This research study helps management, in general, by fulfilling a need for supplying data. The study has also shown how this data may be supplied in a shorter time period than that encountered in the past. The resultant computer printout obtained and presented in Appendix B shows management the data comparing capability which exists within its own company environment. This same capability using other data sources undoubtedly exists in other departments within the company as well as other divisions within the corporation. The identification and establishment of a common data system either within a company or even an entire corporation can prove to be of great value. Not only will a common data system provide a communications bonding between the data users but it will also help to eliminate the duplication of task efforts. This duplication of effort is all too common not only within business but also in government. Also implied by the findings of the research study is the fact that available data can be very valuable and that it is not always necessary to seek and estimate those unknown factors which management needs for decision making. There is an abundance of experience data available if properly used for whatever situation must be confronted.

The use of historical data in a computerized printout also provides a benefit to other departments within the company. It helps to establish a communications link between the various departments as well as establishing a common data base upon which a decision or decisions can be made. Inherent in the use of historical data is the fact that the company is exhibiting the fact that there is an experience factor involved. Being able to exhibit experience in any particular area of endeavor enhances the company's possibility of receiving a contract award. It should be said, without requiring details, that when a department, a company or a corporation understands the confronting situation and works together on a common basis of data, then progress will be more defined as well as controllable. This ultimately enhances overall progress and efficiency in permitting the ultimate in business — — being able to better compete in today's business environment. However, it must be remembered that a computerized analysis model is only a part of the overall proposal/study task. This study should give insight into other areas within the overall project task response which could possibly be adapted to a model. This would further facilitate the efficient use of time and effort.

SELECTED BIBLIOGRAPHY

SELECTED BIBLIOGRAPHY

AFSC-TR-65-2 Prediction-Measurement (Concepts, Tasks Analysis, Principles of Model Construction. Andrews Air Force Base, Maryland, 1965.

AFSCM-375 Systems Engineering Management Procedures. U. S. Government Printing Office, Washington, D. C., 1966.

Brightman, R.W., Data Processing for Decision-Making. New York: The MacMillan Company, 1968.

Glans, J. and others. Management Systems. New York: Holt, Rinehart, and Winston, Inc., 1968.

Lande, H. F., How to Use the Computer in Business Planning. New Jersey: Prentice-Hall, Inc., 1969.

Martin, F. F., Computer Modeling and Simulation. New York: John Wiley and Sons, Inc., 1968.

Matthies, L. H., The Systems Manual. Colorado: Systemation Inc., Colorado Springs, 1967.

McCowen, H. H. and Heimbold, J. J., Development of Universal Data Terminal. New York: Rochester, General Dynamics Electronics Report 166-33, 1966.

MIL-HDBK-226 (NAVY). Design Disclosure for Systems and Equipment. Washington, D. C., Naval Engineering Center, 1968.

APPENDIXES

APPENDIX A

SAMPLE FORMS

of

HISTORICAL DATA

GENERAL DYNAMICS
Fort Worth Division

DATA CONTROL & SEQUENCE NO.	
006-	
SHEET 1	OF 1

MAINTENANCE LEVEL ANALYSIS

1. ITEM NAME	P	F	2. N H A PART NUMBER		3. TRUE MFG PART NO.
4. TRUE MFG NAME			5. FED MFG CODE	6. REFERENCE MCN	7. REFERENCE PRICE

8. QUANTITY PER END ITEM MODEL	QUAN	9. ITEM MCN	10. NEXT HIGHER MCN
1) F-111A	______	1)	1)
2) F-111C	______	2)	2)
3) F-111D	______	3)	3)
4) F-111K	______	4)	4)
5) FB-111	______	5)	5)
6) RF-111	______	6)	6)
7) AGE	______	7)	7).

11. SMR CODE A. CONTR RECMD B. GOV'T DIRECTED	12. PREDICTED MTBF	13. MAINTENANCE FACTOR/100 OPER. HRS. A. CONTR RECMD B. GOV'T DIRECTED		
14. OVERHAUL REPL FACTOR A. CONTR RECMD B. GOV'T DIRECTED	15. GOV'T DIR % NRTS	16. CONDEMNATION FACTOR GOV'T DIRECTED	17. ITEM CODE	
			SYS	LRU	PART/MOD

18. ITEM DESCRIPTION

A. PHYSICAL: WIDTH ______ HEIGHT ______ DEPTH ______ WEIGHT ______ lbs.

B. FUNCTIONAL:

19. DESCRIPTION OF MAINTENANCE TO BE ACCOMPLISHED AT:

A. ORGANIZATIONAL LEVEL: - NONE

B. INTERMEDIATE LEVEL: -

C. DEPOT LEVEL:

DATE

MAINTENANCE SUMMARY
EXHIBIT E

NOMENCLATURE ______ Prepared by ______ Date ______ CONTROL NO ______

CONTRACTOR ______

DESIGNATION/PART NO. ______ Approved by ______ Date ______ MODEL ______

1 RETIREMENT LIFE	3 PROCESS SPEC.	4 PROCUREMENT SPEC	5 DESIGN SPEC	6 MAINT FACTOR	7 R. R. R.	8 A.O.A.	9 T.A.T.

10 PAR POOL QTY	11 BREAK OUT ☐ YES ☐ NO	12 REPL INTERVAL	13 T.B.O.	14 AGERO NO'S REQ'D OR M.A. CONTROL NO.	15 TOTAL MMH/OPER HR.

16 EXTENT OF MAINT

- ☐ THROW AWAY
- ☐ FLEET OR BASE.
- ☐ O & R OR DEPOT
- ☐ COML OVERHAUL

17 TRAINING REQUIREMENTS

PERSONNEL

- ☐ NOT REQUIRED
- ☐ FLEET OR BASE
- ☐ O & R OR DEPOT

HARDWARE

- ☐ MAINT TRAINER
- ☐ OTHER TRAINER

18 DEVIATIONS AUTHORIZED FROM DESIGN SPEC	19 APPL RELIABILITY SPECIFICATIONS

20 APPLICABLE REPORTS	21 DESIGN CHANGES

22

PARED BY: | APPROVED BY | COPIED BY

ALL CARDS

MCN	REQ NO	CHANGE NO	TYPE OF ACTIVITY - CHECK AND KEYPUNCH ONE			DATE MO DA YR
1 … 8	9 10	11 … 15	NEW N 16	DELETE D 16	CHANGE C 16	17 … 22

PART NUMBER (24 … 55) | PART NAME (56 … 80)

NEXT ASSY PART NUMBER (24 … 55) | LOCATION $ (56 … 60) | SC (61 62) | REP (63) | I | RA | TCI | LRJ | M | S | AC | ECP NUMBER — NO R NO (73 … 80)

REQUIREMENT NAME (24 … 43) | RQ LVL (44 45) | MNT LVL (47) | TYPE (48 49) | PREQ FREQUENCY (5 … 55) | FC (56) | ELAPSED TM (57 … 60) | QTY/FR (61 62) | TOP MCN (63 … 70) | DICT. FREQUENCY (71 … 76) | DT | YT (77 … 80)

TECHNICAL JUSTIFICATION

CC	T.J. CODE	L.N.	
6			
6			80
23	24 25	2	27 …

CC	MAN NO	BIS	AFSC/RATING	MAN MIN	AC	MAN NO.	BIS	AFSC/RATING	MAN MIN	AC	MAN NO	BIS	AFS C/RATING	MAN MIN	AC
7															
7															
7															
23	24 25	26	27 … 33	34 … 37	38	39 … 41	42	… 48	49 … 52	53	54 55	56	57 … 63	64 … 67	68	69 … 80

CC	TOOL REF	TOOL PART NUMBER	TOOL NAME	TOTAL MINS	TOOL MEAN NUMBER P AGERD SUFF	TOOL QTY	AC
9							
9							
9							
9							
9							
9							
23	24 25	26 … 45	46 … 60	61 … 64	5 66 … 69 7 … 72	73 74	75	7 … 80

Page ______ of ______

1

RELIABILITY AND DESIGN DATA

EXHIBIT A

Nomenclature	Prepared By ______ Date ______	NEAR Control No.
		Contractor
Designation/Part Number	Approved By ______ Date ______	Model

Military Essentiality

Mission Effect		Existence of Redundancy		Existence of Alternatives	
Total (2)	☐	None (2)	☐	None (2)	☐
Partial (1)	☐	Some (1)	☐	Some (1)	☐
None (0)	☐	Complete (0)	☐	Equiv (0)	☐

3 Operating Life

Retirement Life ______ Source ______

TBO ______ Source ______

Mean Time Between Maintenance Action (Unscheduled) ______

4 Mean Time Between Failures

Design ______ Source ______

Actual ______ Source ______

Estimated ______ Source ______

Scheduled Maintenance Interval ______

5 Probable Modes of Failure

6 Probable Results of Failure & Effect on Safety

7 Fail Safe Characteristics

8 Secondary System

9 Failure History

10 Similar or Same Parts in Similar Installation

Part Number	Model Used In	Design Life	Actual MTBF	Difference in Part Application

ORM 1117 F 5/64

MAINTENANCE TASKS
WORK COPY

NOMENCLATURE

DESIGNATION/PART NUMBER

PREPARED BY

APPROVED BY

DATE

DATE

MEAR CONTROL NO.

GENERAL DYNAMICS
Fort Worth Division

CONTRACTOR

111 AGE

MODEL

GD Electronics Division

quirement Task No	3. Task	4 Work Area Code	5 Task Time

. DYNAMICS
ivision

PREP

MAINTENANCE REQUIREMENTS TASK ANALYSIS - EXHIBIT D

2 PART NUMBER	3 PART NAME	4 NEXT ASSEMBLY

REQUIREMENT NAME	10 REQ CD	11 INT	12 TYPE CODE	13 FREQ.	14 EL TM	15 TOTAL MAN MIN	16 QTY FREQ	1A SUB MEA

OOL EF NO	22 TL QTY	23 TOTAL TIME/ TASK	24 TASK DESCRIPTION	25 CARD CODE	26 TOTAL MAN MINS	27 BIS	28 AFSC OR RATING	29 MAN NO	30 ELAPSED TIME-MIN
									2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42

TOTAL REQ. TIME

39 TOTAL TIME/ AFSC	40 BIS	41 AFSC/RATING	42 NO. PERS	46 SPECIAL TOOLS & AGE TIME ANAL
43 TOTAL		44	45 TOT PERS	

PREPARED BY ______ DATE ______ APPROVED BY ______ DATE ______

SHEET ______ OF ______

EMBLY	5 QTY NA	6	7 CARD CODE	18 TECHNICAL JUSTIFICATION
MEAR NO.			17 CARD CODE	

E-MINUTES

34 36 38 40 42 44 46 48 50 52 54 56 58 60

REPAIRS PARTS DATA

31 PART NO	32 PART NAME	33 PRT QTY	34 MAINT QTY FACTOR	35	36 SHELF LIFE	37 CARD CODE

ME ANALYSIS

SPECIAL TOOL AND AGE REQUIREMENT DATA

47 TOOL REF NO	48 TOOL PART NO.	49 TOOL NAME	50 TOTAL MINUTES	51 MEAR NO. AGERD	SUF	52 TOOL QTY	53 CARD CODE

APPENDIX B

COMPUTER PRINTOUT

NEWSYSTEM SIMULATION

P/N AND NOMENCLATURE	SYS TRU	CSC GD	CONT MODE	GENERAL DATA: MTBF HR	MTBMA HR UNSCHED	MAINT MAN-MIN PER OPER HR	ACTIVE DOWN-TIME MINUTES: UN-SCH	SCHEDULED TIME	SCHEDULED INTER	UNSCH… TRA	TRT	RE…
A 11446 POWER DISTR (1EACH)	V	G	M	103527	20725	0.0100	36	9	1800	6	7	
A 11628 CONTROL POWER SUPPLY (1EACH)	V	G	B	11744	4691	0.0286	35	23	1800	4	11	
A 37350 DATAC (1EACH)	V	G	B	998	474	0.0927	48	0	0	4	25	
A 11381 CONT T P SELECTOR (1EACH)	V	G	A	3139	2103	0.0185	46	0	0	7	11	
A 11382 CONT STIMULUS (1EACH)	V	G	A	4613	3170	0.0101	43	0	0	11	12	
A 11566 AIR COOLER (1EACH)	V	C	M	88495	88495	0.0870	40	15	1M	6	0	
A 11225 SIGNAL GEN (1EACH)	V	G	B	1164	809	0.1020	74	20	1800	7	27	
A 16026 OSCP (1EACH)	V	C	M	2397	2397	0.0249	19 0	13 0	1800 0	6 0	0 0	
A 11942 POWER SUPPLY (1EACH)	V	C	B	7072	7072	0.0107	24	8	1800	11	0	

UPTION

EXHIBIT B
NEWSYSTEM SIMULATION
(Sheet 1 of 2)

SSURANCE

6-1970

DETAILED DATA

	MAINTENANCE TASK DATA								SPECIFICS			
	UNSCHEDULED(MIN)					SCHEDULED			REPAIR TIME		MAINT FACTOR	
	TRA	TRT	REPAIR	R/R	FT	MINUTES	INTER	C				
DD	6	7	0- 19	0- 0	4	0- 9	180D	C	8	27	0	0
DD	4	11	0- 16	0- 0	4	0- 23	180D	C	5	20	0	0
)	4	25	0- 14	0- 0	5	0- 0	0		12	40	0	0
	7	11	0- 20	0- 0	8	0- 0	0		7	31	0	0
	11	12	0- 20	0- 0	8	0- 0	0		9	20	0	0
	6	0	0- 29	0- 0	5	0- 15	1M	S	14	34	0	0
	7	27	0- 32	0- 0	8	0- 20	180D	C	10	55	0	0
DD	6	0	0- 0	0- 10	3	0- 10	180D	I	0	0	0	0
)	0	0	0- 0	0- 0	0	0- 3	180D	F	0	0	0	0
DD	11	0	0- 0	5- 10	8	0- 8	180D	C	0	0	0	0

THE FOLLOWING VALUES ARE FOR THE SYSTEM F

MTBF =MEAN TIME BETWEEN FAILURES
MTBMA=MEAN TIME BETWEEN MAINTENANCE ACTIONS
MTBM =MEAN TIME BETWEEN MAINTENANCE
MMM =MAN MINUTES PER OPERATING HOUR
MTTR =MEAN TIME TO RESTORE
MPT =MEAN ACTIVE PREVENTIVE MAINTENANCE TIM
MTPMA=MEAN TIME BETWEEN PREVENTIVE MAINTENAN
BARM =MEAN MAINTENANCE TIME
AI =INHERENT AVAILABILITY
AA =ACHIEVED AVAILABILITY
LAMB =FAILURE RATE

THE VALUES OF AI,AA AND LAMBDA WERE CALCULATED

$$AI = \frac{MTBF}{MTBF + MTTR} \qquad AA = \frac{MTBM}{MTBM + BARM}$$

EXHIBIT B
NEWSYSTEM SIMULATION
(Sheet 2 of 2)

```
R THE SYSTEM FORMED WITH THE TRU GIVEN

ES                                   =        327HOURS
NANCE ACTIONS (UNSCHEDULED)=        201HOURS
NANCE                                =         64HOURS
G HOUR                               =   0.3345MINUT
                                     =         50MINUT
AINTENANCE TIME                      =         15MINUT
TIVE MAINTENANCE ACTIONS             =         94HOURS
                                     =         26MINUT
                                     =  0.99745
                                     =  0.99328
                                     =  0.00306


 WERE CALCULATED WITH THE FOLLOWING FORMULAS


*****************************************************
                                                    *
       MTBM                              1          *
   ---------------         LAMBDA=    ------        *
   MTBM + BARM                          MTBF        *
                                                    *
*****************************************************
```